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RESEARCH PROGRAM
Foliage-feeding Insects Affecting Trees

NOT FOR PUBLICATION

# Spruce Budworm Population-Damage Study

Progress Report

1957

By

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Prepared by

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# SPRUCE BUDWORM POPULATION-DAMAGE STUDY

PROGRESS REPORT

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## SUMMARY

1. No significant difference in larval populations exists in sampling between 2nd through 5th instar larvae, but a highly significant difference exists between these stages and the 6th instar and pupal stages.

2. A highly significant difference in larval and pupal populations exists between sampling low-crowns versus mid- and top-crowns, but no difference exists between mid- and top-crown.

3. Buds, or new growth tips, are evenly distributed throughout the crown of Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco), but distributions within alpine fir (Abies lasiocarpa (Hook.) Nutt.) parallels the larval distribution (#2).

4. There was an average of 24.90 buds per 15-inch twig on Douglas-fir; 96.90 on alpine fir. After defoliation, residual buds averaged 16.17 on Douglas-fir; 14.47 on alpine fir. Cumulative defoliation was 35.06 percent on Douglas-fir and 85.06 percent on alpine fir.

5. Residual larval population was 0.57 per 15-inch twig on Douglas-fir; 5.65 on alpine fir.

6. Total buds, or new growth tips, partially or completely eaten per larva were 8.98 on Douglas-fir; 8.64 on alpine fir.

7. A significant regression of cumulative defoliation on the original larval population was found for Douglas-fir; such could not be shown, at present, for alpine fir. This is probably due to the statistical distribution of alpine fir buds.

8. Total parasitism was 11.11 percent for both plots for the early larval samples; 25.00 and 22.69 percent for the Douglas-fir and alpine fir plots, respectively, for mature larvae and pupae.

9. Scarcity of egg masses precluded analysis of their distribution in the tree crown.

10. Diapause of the overwintering larvae was broken by subjecting the larvae to (1) 32° to 40° F. for 1 week, (2) -25° F. for 8 hours, and (3) 70° F. until emergence. An average of 22.25 days elapsed for emergence to begin.

11. Total parasitism of overwintering larvae was 11.11 percent as compared to 20.00 percent in 1956 for plot En-1. Plot Ex-4 was not sampled for this phase.

## GENERAL

The first complete year of research on spruce budworm (Choristoneura fumiferana (Clem.,)) in southern Idaho was completed in the spring of 1958. For convenience of the study, this and succeeding annual progress reports will cover the period from emergence in the spring through overwintering larvae. The bulk of the work in this type of study will center upon the larval stages. It is hoped that in the future more basic research can be conducted on the other life stages. Most of the work was carried out as outlined in the study plan.

The work accomplished during 1957 is largely fundamental and a necessary step toward the final objective: "What constitutes a damaging population?" Probably the greatest result of the work this year was developing ideas for future study, which will be brought out in a study plan amendment.

The word "bud," as used in this report, will mean the new bud and, as it develops,, the new growth tip.

## OBJECTIVES

The objectives for the 1957 season are shown below as used in the study plan. Phases I and II have been combined for reporting purposes since Phase II is a continuation of Phase I.

### Phase I - II.--Larval Development and Cumulative Defoliation

1. To determine the distribution of the larvae, damaged buds, and total bud population within a tree crown throughout the larval development period.

2. To determine the average number of larvae, green buds and damaged buds per 15-inch twig within 3 different crown levels throughout the larval development period.

3. To correlate the larval population with the cumulative defoliation.

4. To identify and inventory parasites of the larval stages.

Phase III.--Adults

1. To determine percent of moth emergence from pupal cases.

Phase IV.--Egg Mass

1. To determine egg mass distribution within the tree crown.

Phase V.--Forced Emergence of Overwintering Larvae

1. To determine best combination of temperatures and length of exposure to break diapause.

2. To determine extent of parasitism.

## METHODS

Four study plots were established to attain these objectives. However, only 2 of these plots could be studied because of increased workloads and limited manpower.

Plot En-1 is predominantly Douglas-fir; very little spruce, lodgepole pine, and alpine fir are present. The plot lies in a creek bottom, facing north at 5,550 feet elevation. The budworm infestation was first reported in 1949. Annual surveys have shown that this infestation fluctuates in intensity.

Plot Ex-4 is predominantly alpine fir mixed with Douglas-fir. The stand is fairly open and has a west exposure on a summit at 7,000 feet elevation. Infestation began about 1954, adjacent to the boundary of the 1955 control project, and heavy defoliation has been reported annually since 1955.

Descriptions of trees sampled within each plot follows.

Table 1.--Trees sampled during the 1957 season of budworm study in southern Idaho

| Plot | Tree number | Species | D.b.h. | Height | Tree position | Vigor class 1/ | Crown length |
|---|---|---|---|---|---|---|---|
| | | | (inches) | (feet) | | | (feet) |
| En-1 | 1 | D.F. | 4.0 | 22 | Understory | 1 | 17 |
| | 2 | D.F. | 9.7 | 40 | " | 1 | 34 |
| | 3 | D.F. | 7.1 | 40 | " | 3 | 35 |
| | 4 | D.F. | 8.1 | 42 | " | 2 | 33 |
| | 5 | D.F. | 6.3 | 37 | " | 3 | 26 |
| Ex-4 | 1 | A.F. | 10.7 | 63 | Codominant | 1 | 60 |
| | 2 | A.F. | 11.3 | 42 | " | 1 | 39 |
| | 3 | A.F. | 8.5 | 32 | Understory | 1 | 30 |
| | 4 | A.F. | 12.0 | 35 | Codominant | 1 | 34 |
| | 5 | A.F. | 6.9 | 21 | Understory | 1 | 21 |

1/ Vigor graded 1 - 4; 1 = best, based on form and needle complement.

## Phase I - II

Four 15-inch twigs were taken from each third of crown (low, mid, and top). This division was made visually and depended upon length of crown rather than on the number of twigs per third. Four samples were taken during the larval period; 1 during Phase I, and 3 during Phase II. The numbers of larvae, total buds (new growth tips), and defoliated tips were recorded. Twig collections were made with pole pruners and basket similar to those used by the Pacific Northwest Forest and Range Experiment Station.

## Phase III

For Phase III 50 pupae per tree were collected and placed inside number 000 capsules for observation of moth emergence.

## Phase IV

Two whole branches were taken from the mid-crown of each of three Douglas-fir and three alpine fir trees.

## Phase V

The results of the 1956 season indicated that diapause might be broken if the larvae were subjected to sub-zero temperatures for a short duration. Twenty-four log billets (6 to 8 inches in diameter x 15 inches long) were cut to test the temperature-time effect needed to break diapause. Twelve logs were cut from each of 2 Douglas-fir trees from plot En-1. All logs were first stored for 1 week at a temperature range of 32° to 40° F. After this period 4 billets each were stored under the following temperature-time conditions:

| -25° F. | 32° to 40° F. |
|---|---|
| 8 hours | 7 days |
| 24 hours | 14 days |
| 7 days | 25 days |

At the end of each period the billets were removed to a constant temperature room where the average daily cumulative temperature was 33.45 degrees. The cumulative daily temperature was calculated by taking the difference between 42° F. and the average of the daily maximum and minimum temperatures. The total number of cumulative degrees for the project was then divided by the total number of days of the project to derive the average daily cumulative temperature. A 5-gallon ice cream container was used as a cage throughout the experiment.

## RESULTS

Budworm larval populations follow the negative binomial distribution; consequently the transformation ($y = \log_{10} X + 1$) of the data to a normal distribution is necessary before an analysis of variance can be calculated.

## Phase I - II

Sample 0 refers to the first sample taken, or Phase I; samples 1, 2, and 3 to Phase II. Table 2 shows the larval development at the time of each sample.

Table 2.--Larval population by instar at time of sampling

| Plot | Date | Sample | Larval instars by percent | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | P | |
| En-1 (DF) | 7 June | 0 | 2.6 | 54.4 | 33.3 | 9.7 | 0 | 0 | 100 |
| | 17 June | 1 | 6.8 | 32.2 | 48.3 | 12.7 | 0 | 0 | 100 |
| | 1 July | 2 | 0 | 6.4 | 26.4 | 23.6 | 43.6 | 0 | 100 |
| | 17 July | 3 | 0 | 3.1 | 3.1 | 15.6 | 56.3 | 21.9 | 100 |
| Ex-4 (AF) | 11 June | 0 | 12.7 | 75.1 | 12.2 | 0 | 0 | 0' | 100 |
| | 20 June | 1 | 23.6 | 41.2 | 30.3 | 4.9 | 0 | 0 | 100 |
| | 8 July | 2 | 0.1 | 11.2 | 24.9 | 20.9 | 40.8 | 2.1 | 100 |
| | 22 July | 3 | 0 | 0 | 3.6 | 4.7 | 15.3 | 76.4 | 100 |

An analysis of variance showed a significant difference between times of sampling, between plots (tree species), and between crown positions (table 3).

Table 3.--Analysis of variance of budworm larval distribution

| Source | Sum of squares | Degrees of freedom | Mean square | F value |
|---|---|---|---|---|
| Time of sampling | 2.980 | 3 | 0.993 | 17.12** |
| Plot | 21.026 | 1 | 21.026 | 362.52** |
| Crown position | 0.864 | 2 | 0.432 | 7.45** |
| Time x plot | 0.030 | 3 | 0.010 | < 1 |
| Time x position | 0.527 | 6 | 0.088 | 1.52 |
| Plot x position | 0.135 | 2 | 0.068 | 1.17 |
| Time x pl. x pos. | 0.438 | 6 | 0.073 | 1.26 |
| Residual | 5.601 | 96 | 0.058 | |
| Total | 31.601 | 119 | | |

Independent comparisons were then made. They showed no significant difference between the first 3 samples, but a highly significant difference between the first 3 and the fourth sample (table 4). Further tests showed a significant difference between the low-crown versus mid- and top-crown for either or both Douglas-fir and alpine fir, but no significant difference between mid-versus top-crown in either or both species (table 5).

Table 4.--Independent comparison between times of sampling budworm larval population

| Effect | Time of sampling | | | | Mean square | F value |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | | |
| A | -1 | -1 | -1 | +3 | 2.605 | 44.91** |
| B | +2 | -1 | -1 | 0 | 0.374 | 6.45 |
| C | 0 | +1 | -1 | 0 | 0.000 | --- |

Table 5.--Independent comparison between crown positions per tree species

| Plot | Effect | Crown position | | | Mean square | F value |
|---|---|---|---|---|---|---|
| | | Low | Mid | Top | | |
| En-1(DF) | A | -2 | +1 | +1 | 0.340 | 5.86* |
| | B | 0 | -1 | +1 | 0.012 | < 1 |
| Ex-4(AF) | A | -2 | +1 | +1 | 0.489 | 8.43** |
| | B | 0 | -1 | +1 | 0.157 | 2.71 |

Coefficients of variation were calculated and the accuracy of the sampling is shown in table 6. The sample size needed to attain either a coefficient of variation of 20 percent or 10 percent at a 95 percent confidence level is shown in table 7.

Table 6.--Sample means, standard errors, and coefficients of variation based on 4 twigs per tree

| Sample | Tree species | Crown position | N (twigs) | Mean no. larvae per twig | S.E. 95% | Coeff. var. (95%) |
|---|---|---|---|---|---|---|
| Early instars | DF | L | 20 | 1.20 | 0.69 | 57.50 |
| | | L | 20 | 1.20 | 0.54 | 45.19 |
| | " | M | 20 | 2.25 | 0.98 | 43.56 |
| | " | M | 20 | 2.75 | 1.19 | 43.24 |
| | " | T | 20 | 1.70 | 0.67 | 39.41 |
| | " | T | 20 | 2.65 | 0.67 | 25.19 |
| Late instars | DF | L | 20 | 0.45 | 0.33 | 74.17 |
| | " | M | 20 | 0.50 | 0.31 | 62.58 |
| | " | T | 20 | 0.75 | 0.31 | 41.33 |
| Early instars | AF | L | 20 | 5.20 | 1.89 | 36.30 |
| | " | L | 20 | 6.80 | 1.52 | 22.33 |
| | " | M | 20 | 13.35 | 3.29 | 24.69 |
| | " | M | 20 | 16.70 | 3.23 | 19.35 |
| | " | T | 20 | 11.00 | 1.75 | 15.87 |
| | " | T | 20 | 19.35 | 4.71 | 24.34 |
| Late instars | AF | L | 20 | 5.65 | 1.68 | 29.73 |
| | " | M | 20 | 6.80 | 1.53 | 22.55 |
| | " | T | 20 | 4.50 | 1.56 | 34.67 |

Table 7.--Sample size needed for prescribed accuracy at different larval population levels per tree species for mid-crown sampling (15-inch twig basis)

| Larval stage | Tree species | Avg. no. larvae per twig | Avg. no. trees needed for: (based on 4 twigs/tree) 20% - 95% | 10% - 95% |
|---|---|---|---|---|
| Early | DF | 1-2 | 30 | 114 |
| | | 2-3 | 20 | 77 |
| Late | DF | < 1 | 50 | 157 |
| Early | AF | 1-5 | 18 | 66 |
| | | 6-10 | 7 | 25 |
| | | > 10 | 6 | 23 |
| Late | AF | 4 | 16 | 61 |
| | | 5 | 12 | 44 |
| | | > 6 | 7 | 26 |

The analysis of variance test confirms the average shown in table 8.

Table 8.--Average number of larvae, damaged buds, and total buds per 15-inch twig within each crown position per sample per plot

| Plot | Sample | Crown positions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Larvae | | | Damaged buds | | | Total buds | | |
| | | Low | Mid | Top | Low | Mid | Top | Low | Mid | Top |
| En-1(DF) | 0 | 1.20 | 2.45 | 1.70 | 1.35 | 2.55 | 1.75 | 19.20 | 28.00 | 27.70 |
| | 1 | 1.20 | 2.75 | 2.05 | 1.45 | 3.30 | 2.20 | 17.20 | 27.85 | 27.40 |
| | 2 | 1.65 | 1.70 | 2.15 | 3.75 | 5.45 | 6.65 | 16.45 | 28.40 | 26.40 |
| | 3 | 0.45 | 0.50 | 0.75 | 6.90 | 10.25 | 9.05 | 21.40 | 25.80 | 27.50 |
| Ex-4(AF) | 0 | 5.20 | 13.25 | 11.00 | 5.45 | 13.25 | 11.05 | 66.80 | 105.95 | 101.66 |
| | 1 | 6.80 | 16.70 | 19.35 | 7.15 | 16.90 | 20.85 | 50.95 | 118.20 | 112.25 |
| | 2 | 12.60 | 16.40 | 10.30 | 30.10 | 76.95 | 76.90 | 50.40 | 114.15 | 112.70 |
| | 3 | 5.65 | 6.80 | 4.50 | 69.75 | 91.80 | 85.75 | 80.40 | 104.95 | 105.35 |

It would appear, at least for the year 1957, that the variance of the damaged bud population is similar to that of the larval population. However, the distribution of total buds (or new growth tips) differs slightly from the larval distribution. Within Douglas-fir the buds are distributed uniformly throughout the crown. Within alpine fir the total bud distribution shows a highly significant difference exists between low-crown versus mid- and top-crown, but no significant difference between mid and top. This parallels the larval distribution.

Table 9 shows the amount of available food supply, number of larvae, and ultimate defoliation on a 15-inch twig basis. In view of the great difference between percent of ultimate defoliation for each plot, two items stand out: (1) the similarity of the residual bud population of the two tree species (16.17 on Douglas-fir and 14.47 on alpine fir), and (2) the total buds per tree species eaten per larva (8.98 on Douglas-fir and 8.64 on alpine fir). The extent of individual bud damage was visually estimated using the standards:

0 - 50 percent defoliated - light
50 - 75 percent defoliated - medium
75 - 100 percent defoliated - heavy

Of the total buds eaten per larva on Douglas-fir:

5.16 buds fell into the light defoliation class
2.16 buds fell into the medium defoliation class
1.66 buds fell into the heavy defoliation class

8.98 total buds defoliated.

The breakdown for alpine fir is:

1.76 buds fell into the light defoliation class
1.38 buds fell into the medium defoliation class
5.50 buds fell into the heavy defoliation class

This reversed effect between tree species might be attributable to number of larvae present.

Table 9.--Larval and bud population and defoliation per larva per plot on a 15-inch twig basis

| Tree species | Avg.No. mature larvae | Avg. no. buds prior defoliation | Avg. no. buds past defoliation | Percent defoliation | Avg. no. buds eaten per larva |
|---|---|---|---|---|---|
| DF | 0.57 | 24.90 | 16.17 | 35.06 | 8.98 |
| AF | 5.65 | 96.90 | 14.47 | 85.06 | 8.64 |

The probable influence of parasites upon the later instars of the larval population was disregarded in attempting to correlate larval populations and cumulative defoliation. A significant correlation was computed for plot En-1 (D.F.) (figure 1). The equation took the form $y = 39.843 x + 5.502$. The confidence band was based on a 95 percent probability. A similar regression was not found significant for plot Ex-4 (A.F.), possibly because of the statistical distribution of the alpine fir buds. Data from larval samples 0 and 1 and defoliation sample 3 were used for this correlation.

All larvae collected were preserved and dissected for parasites. The collections were divided into two categories: (1) early and (2) mature larval stages, including pupae. Total parasitism was about equal within both plots; Apantelos fumiferana (Vier.) was the most prevalent (table 10).

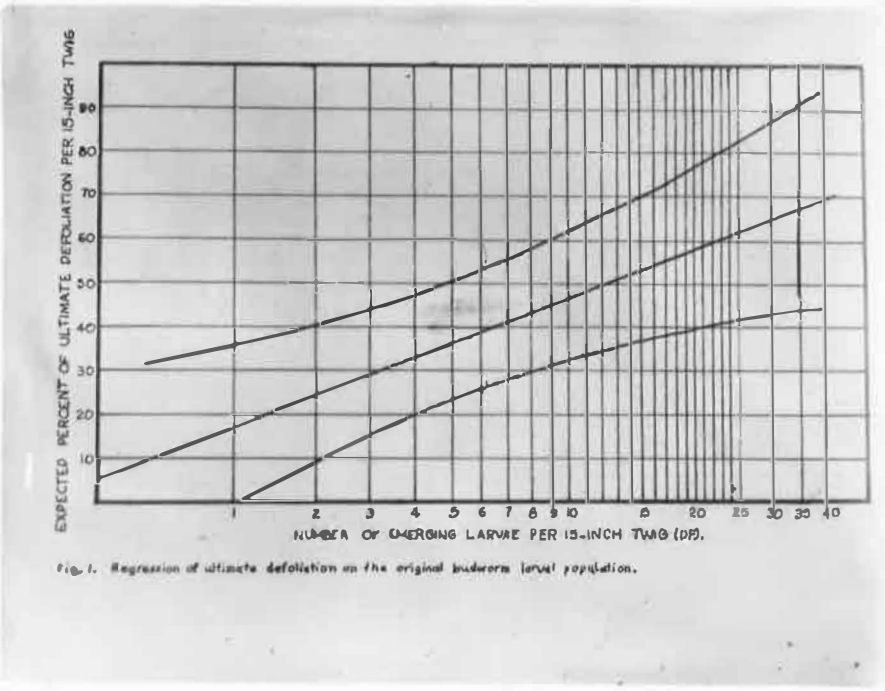

Fig. 1. Regression of ultimate defoliation on the original budworm larval population.

Figure 1. Regression of ultimate defoliation on the original budworm larval population

Table 10.--Parasitism of budworm larval populations by percent within study plots

| Plot | Larval stage | Apanteles fumiferana | Glypta fumiferana | Horogenes | Total parasitism |
|---|---|---|---|---|---|
| | | (%) | (%) | (%) | (%) |
| En-1 | early | 11.11 | -- | -- | 11.11 |
| Ex-4 | early | 4.44 | 6.39 | 0.28 | 11.11 |

| | | Apant. | Glypta | Actia | Agria | Phryxe or Madremyia | Lypha | Cero-masia | Phoro-cera | Total para-sitism |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (%) | (%) | (%) | (%) | (%) | (%) | (%) | (%) | (%) |
| En-1 | Mature | 13.39 | 8.04 | 0.89 | 0.89 | 0.89 | 0.89 | -- | -- | 25.00 |
| Ex-4 | Mature | 13.73 | 5.67 | -- | 2.09 | -- | -- | 0.30 | 0.90 | 22.69 |

Weekly collections of 100 budworm larvae were shipped to Dr. E. C. Clark at the University of Idaho for disease detection. No disease was found.

## Phase III

Moth emergence from pupal cases produced rather disappointing results. Heat caused collapse of the capsules; thus emergence might have been affected, and the resulting data are unreliable.

## Phase IV

Determining the egg mass distribution within a tree crown became rather difficult--particularly since egg masses were scarce.

Only 1 egg mass was found on the 2 trees sampled in plot En-1. Two workers examined 102 feet of branch surface. The amount of branch surface examined per crown position is shown below (table 11).

Table 11.--Whole branch surface examined by crown position within plot En-1

| Tree sp. | Tree ht. | Sample height | No. of sq. ft. | Sample height | No. of sq. ft. | Sample height | No. of sq. ft. | Total sq. ft. |
|---|---|---|---|---|---|---|---|---|
| | (feet) | (feet) | | (feet) | | (feet) | | |
| AF | 78 | 19 | 16 | 45 | 9[1/] | 70 | 5 | 30 |
| DF | 59 | 14 | 34 | 31 | 28 | 54 | 10 | 72 |

1/ Only 1 egg mass found

However, on plot Ex-4 a few egg masses were found, yet not to the extent that would allow statistical tests. The data are shown in table 12.

Table 12.--Egg mass data per 10 square feet of branch surface for plot Ex-4

| Tree sp. | Tree ht. | Low crown | | Mid crown | | Top crown | | Total sq. ft. | E.M. per 10 sq.ft. |
|---|---|---|---|---|---|---|---|---|---|
| | | Sample height | E.M. per 10 sq.ft. | Sample height | E.M. per 10 sq.ft. | Sample height | E.M. per 10 sq.ft. | | |
| | (ft.) | (feet) | | (feet) | | (feet) | | | |
| AF | 63 | 15 | 2.5 | 30 | 2.1 | 55 | 1.4 | 42 | 2.1 |
| AF | 40 | 12 | 0.5 | 20 | 0 | 38 | 0 | 45 | 0.2 |
| AF | 30 | 7 | 0 | 14 | 0 | 26 | 3.5 | 36 | 0.6 |
| DF | 51 | 12 | 2.9 | 30 | 5.8 | 50 | 0 | 32 | 3.8 |
| DF | 40 | 8 | 0 | 20 | 5.0 | 37 | 3.0 | 57 | 2.1 |
| DF | 19 | 7 | 0.8 | 13 | 1.0 | 18 | 0 | 36 | 0.8 |

## Phase V

The following tables show the results of breaking diapause.

Table 13.--Temperature-time conditions for breaking diapause of overwintering budworm larvae

| Temp. | Time | Number larvae emerged | Number sq. in. bark | Larvae per 100 sq. in. | Avg. number days prior emergence | Avg. no. days to cease | Total days from cutting to completion |
|---|---|---|---|---|---|---|---|
| -25°F | 8 hrs. | 105 | 1121.5 | 9.39 | 22.25 | 26.25 | 55.50 |
| -25°F | 24 hrs. | 46 | 1087.5 | 4.23 | 25.25 | 17.25 | 48.50 |
| -25°F | 7 da. | 1 | 1185.0 | 0.08 | -- | -- | -- |
| +40°F | 7 da. | 50 | 1372.5 | 3.59 | 21.50 | 16.50 | 42.75 |
| +40°F | 14 da. | 101 | 1305.0 | 7.62 | 23.25 | 16.50 | 54.25 |
| +40°F | 25 da. | 144 | 1250.0 | 10.64 | 15.33 | 27.33 | 66.67 |

The value of -25° F. for 8 hours can be shown better below.

Table 14.--Means, sampling errors, and coefficient of variation based on 95 percent confidence level for breaking diapause

| Condition | Mean no. of emerging larvae per 100 sq. in. of bark | Sampling error | Coefficient of variation |
|---|---|---|---|
| | | | (percent) |
| -25°; 8 hours | 9.39 | 1.95 | 20.77 |
| -25°; 24 hours | 4.23 | 0.84 | 19.86 |
| -25°; 7 days | 0.08 | 0.075 | 93.75 |
| +40°; 7 days | 3.59 | 1.48 | 41.23 |
| +40°; 14 days | 7.62 | 3.26 | 40.16 |
| +40°; 25 days | 10.64 | 3.80 | 35.71 |

The daily cumulative temperature within the cages ranged between 504 and 810 degrees, averaging 684 degrees before emergence began, or an average of 20.45 days. An average of 33.45 degrees was accumulated daily.

Dissection of all emerged larvae (447) showed 11.11 percent total parasitism. Dissection made the previous year showed 20 percent.